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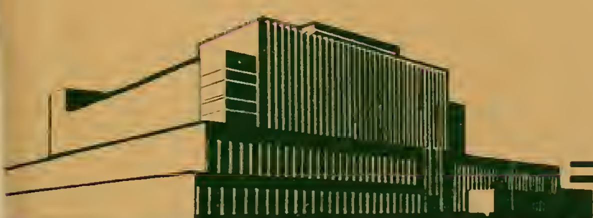

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UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE
In Cooperation with the University of Wisconsin

MAXIMUM MOISTURE CONTENT METHOD FOR

DETERMINING SPECIFIC GRAVITY OF SMALL WOOD SAMPLES

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Summary

A new technique is described for determining the specific gravity, on a green volume basis, of small wood samples, such as portions of increment cores. The technique uses the well-known relationship between maximum moisture content and specific gravity and obviates the direct determination of the volume of the sample. It has certain advantages over the mercury- and water-immersion methods.

Introduction

It is generally recognized that the strength properties of wood and yields of pulp are closely related to the density of a species. Growth-quality studies are designed to determine the influences of conditions of growth and wood structures upon wood quality, where "quality" is expressed in terms of wood density or specific gravity. When such studies are related to forest management research conducted on permanent sample plots, the accurate determination of specific gravity for samples from living trees is of paramount importance.

The specific gravity of wood is defined as the weight of the ovendry wood divided by the weight of a volume of water equal to the volume of wood under the moisture conditions at test. The volume may be that of the wood when ovendry, when green, or at some intermediate

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[1] Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

moisture condition. Due to the possible unequal shrinkage behavior of wood in drying from the green to the ovendry condition, specific gravity on the basis of ovendry weight and green volume usually is preferred in growth-quality studies and in other cases where comparisons are made.

Specific Gravity by Maximum Moisture Content

Basically, there are two approaches to the determination of specific gravity of small wood samples. The first is the weight-volume method. If the metric system is used, then 1 gram is the weight of 1 cubic centimeter of water, and the formula for specific gravity becomes:

$$G_f = \frac{m_o}{V_f} \text{ or } G_o = \frac{m_o}{V_o} \qquad (1)$$

where G_f and G_o are the specific gravities of the wood sample based on green and ovendry volumes, respectively; m_o is ovendry weight in grams; V_f is green volume in cubic centimeters; and V_o is ovendry volume in cubic centimeters. There are several methods for obtaining the volume of exceedingly small wood samples, such as the mercury-displacement, water-immersion, and the photometric method -- these methods will be discussed later.

The relationship between the specific gravity of a piece of wood and its maximum moisture content offers a new method of determining the specific gravity of small samples, as has been demonstrated by Dr. Keylwerth (4),[2] who was the first to use this method. From the maximum water content of the completely saturated wood, the specific gravity of the wood (based on green volume) is determined directly without first having to obtain the volume of the sample. The following gives the derivation of the formula:

$$M_{max} = \frac{m_m - m_o}{m_o}$$

$$= \frac{m_w}{m_o}$$

$$= \frac{V_f - V_{so}}{m_o}$$

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[2]Underlined numbers in parentheses refer to the list of numbered references at the end of the report.

$$= \frac{V_f}{m_o} - \frac{V_{so}}{m_o}$$

where M_{max} is maximum water content in grams of water per gram of ovendry wood; m_m is mass of water-saturated wood in grams; m_w is mass of water in the wood in grams; V_{so} is volume, in cubic centimeters, of the ovendry cell walls constituting the wood sample.

From formula (1) this becomes:

$$M_{max} = \frac{1}{G_f} - \frac{1}{G_{so}}$$

where G_{so} is the specific gravity of wood substance comprising the cell walls, and from this it follows that:

$$G_f = \frac{1}{M_{max} + \frac{1}{G_{so}}} \qquad (2)$$

Stamm (7) has shown that the density of wood substance is relatively constant and varies only slightly among species as a result of variation in chemical composition of the species. The specific gravity of wood substance, as determined by the water-displacement method, varies between 1.50 and 1.56 and has an average value of 1.53.

The maximum moisture content technique has recently been used at the Forest Products Laboratory to determine the specific gravity based on the green volume of small samples of loblolly pine. The samples were increment cores or 1/2-inch diameter plugs that ranged in volume from 300 to 3,000 cubic millimeters.

Immediately after the cores were taken in the field, they were numbered and placed in corked glass vials with a fungicide in water as a preservative and to assure a saturated humidity. The vials were held in cold storage until the work was ready to proceed.

The cores were then surfaced with a very sharp knife to remove the crushed surface fibers. The particular growth period for study, which in this case included five growth rings, was separated with the aid of a dissecting microscope. Then the cores were numbered and placed in vacuum flasks with distilled water. Since the cores had been kept in the green condition they usually sank. A vacuum was applied to the flasks until the samples had absorbed water to a maximum constant

weight. In practice, this took from 4 to 5 days; therefore, a vacuum was applied intermittently for 10 days to insure saturation.

To obtain the specific gravity of a wood sample by the maximum moisture content method, only the weight in air of the saturated wood sample and the ovendry weight of the same sample need be determined.

Because of the smallness of the samples, weighing bottles were used to avoid loss or gain of moisture (and therefore change in weight), which could contribute considerable error. The samples were weighed on an automatic semimicrobalance, which read to 1/100 milligram. The work was done in a room in which temperature and humidity were controlled.

The vacuum flasks containing the wood samples and the weighing bottles were allowed to come to equilibrium temperature in the controlled room over night before the soaked weights were determined. A sample was taken from the vacuum flask, and the excess surface water was removed with a damp cloth. The difference in the two weights of weighing bottle and weighing bottle plus sample gave the weight of the saturated wood sample (m_m). The samples were dried in an oven at 100° to 105° C. until a substantially constant weight was obtained and then transferred rapidly to a dessicator and allowed to reach equilibrium temperature in the controlled room before the ovendry weight (m_o) was obtained. The specific gravity of the sample was calculated by substitution in the formula:

$$G_f = \frac{1}{\frac{m_m - m_o}{m_o} + \frac{1}{G_{so}}}$$

For the density of wood substance, the average value 1.53 or, if available, the exact value for the species being studied, as obtained by Stamm (7) by the water-displacement method, is substituted for G_{so} in the above formula.

The possible sources of error in obtaining the specific gravity of small wood samples by the above technique are: (1) obtaining the absolute maximum saturation with water; (2) obtaining the soaked weight of the sample in air; (3) assuming that the density of wood substance for a species is a constant; and (4) the possibility of extraneous matter in the sample.

An attempt was made to estimate the error involved in obtaining the soaked weight of the sample. Since the sample is weighed in air, the excess surface moisture must first be removed leaving only a film of essentially uniform thickness over the surfaces of the sample. The larger the surface area of the sample in relation to its volume, the more realistic this error becomes. In practice, the excess surface

moisture was removed with a piece of muslin wrung out in distilled water. It was found that for a sample 1.59 cubic centimeters in volume with a surface area of 7.56 square centimeters, the error amounted to 0.000753 (or 0.0001 gram per square centimeter of surface area) -- a probability of 95 percent when 25 repeated measurements were made on the same wood sample. This contribution to the error term is small in comparison with the possible error caused by a less than maximum moisture content. Therefore, it is necessary that soaking in distilled water under vacuum continue until the sample is absolutely saturated. No attempt was made to evaluate the error due to infiltrated substances as such an error tends to be present in all methods for obtaining the specific gravity of wood samples. Another possible source of error is in assuming the absolute density of wood substance. Stamm found little variation in the density of wood substance between species. If a constant value is used for the density of the cell wall, however, the computed specific gravity, although not necessarily the true specific gravity of the wood, will provide a relative specific gravity factor of value in growth-quality studies.

Discussion of Techniques for Small Samples

In choosing a method for determining specific gravity of extremely small wood samples there are three points which should be borne in mind: (1) the desired accuracy of the determination; (2) the amount of skill required to make the determinations; and (3) the funds available for the study where the speed of the determinations will be a significant factor.

With the weight-volume methods for obtaining specific gravity, the volume of the sample must be determined directly, and these volume determinations are usually the least accurate and the most difficult to obtain. Markwardt and Paul (5) have described in detail methods for obtaining specific gravity on the weight-volume basis. Here, only those techniques will be considered that lend themselves to volume determinations of exceedingly small samples; namely, the mercury- and water-immersion methods.

The mercury-immersion method (1) has been used successfully by a number of research workers for determining the specific gravity of small wood samples on the basis of ovendry volume.[3] Hennig (3) has discussed the possible sources of error due to mercury penetrating into the pores of the wood and has shown how this error may be reduced to a minimum. When the specific gravity is required on the basis of green volume, mercury penetrating into the pores of the wood

[3]Using the Breuil mercury volumeter.

and remaining there in spite of efforts to dislodge it may contribute considerable error to the ovendry weight of the sample. However, Bethel and Harrar (2), have developed a mercury volumeter for determining the green volume of short sections of increment borings. They compared this method with the standard water-immersion method in which a chain-o-matic balance was used and found no significant difference. The Forest Products Laboratory, however, found a significant difference in the volumes obtained by the Breuil mercury volumeter and the water-immersion method when a piece of glass rod was used as the test specimen. The mercury-immersion method gave the greatest variation in volume as well as a consistently larger volume. Some consideration might be given to the fact that the Laboratory mercury volumeter has been in use for over 20 years. It was completely cleaned and overhauled before the test, however, and appeared to be in good working order.

The application of the water-immersion technique to extremely small specimens has been described by Vintila (8) who used it for samples ranging in size from 200 to 1,000 cubic millimeters. It is particularly suited where specific gravity on the basis of green volume is required. For accurate results, the sample should be completely water saturated. When a chain-o-matic balance is used, green volumes may be obtained with a high degree of accuracy because the beam of the balance is at all times horizontal when weights are recorded, and the samples are submerged to a constant depth. When an automatic semimicrobalance is used, allowance should be made for raising or lowering the water level in the container because weights up to 1 milligram are determined from the beam deflection, and the samples are not immersed to a uniform depth. The advantages accruing from the greater speed of weighing with an automatic balance are somewhat lessened by this addition to the procedure. Moreover, the weight of the sample when submerged is the least accurate determination made by the water-immersion technique because the sample acts as a damper, and the balance loses its high sensitivity.

The photometric method for obtaining the specific gravity on a green volume basis has been used by Morschauser (6) for obtaining the specific gravity (or relative density factor) of springwood and summerwood. It is a laborious method requiring thin microscopic sections of wood and photomicrographs of high magnification in order to determine the pore space in the cross section. The method although appropriate for certain kinds of investigations is not well adapted to large-scale growth-quality studies.

The maximum moisture content technique for obtaining specific gravity on the basis of green volume is extremely simple and requires only determinations of the weight of the completely water saturated sample and of the weight of the ovendry sample, both of which may be made with almost equal precision. It is well suited to use with an automatic

balance -- an experienced worker can make as many as 140 weighings per hour (or one weighing in 25 seconds). This factor alone is well worth consideration when choosing a method of specific gravity evaluation in large-scale growth-quality studies based on increment borings. In the maximum moisture content technique, a chance of error exists in assuming a value for the density of the cell wall substance. If the true value is not used, the computed specific gravity will be in error. The error is a constant one, however, and the computed specific gravity will then be a relative density factor, which still has great value in growth-quality studies where comparisons are made.

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